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(54) **FULL-BRIDGE TIP DRIVER FOR ACTIVE STYLUS**

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(73) Assignee: **Cypress Semiconductor Corporation**, San Jose, CA (US)

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G06F 3/0354 (2013.01)
G06F 3/041 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 3/03545*** (2013.01); ***G06F 3/0416*** (2013.01)

(58) **Field of Classification Search**
CPC G06F 3/0416
See application file for complete search history.

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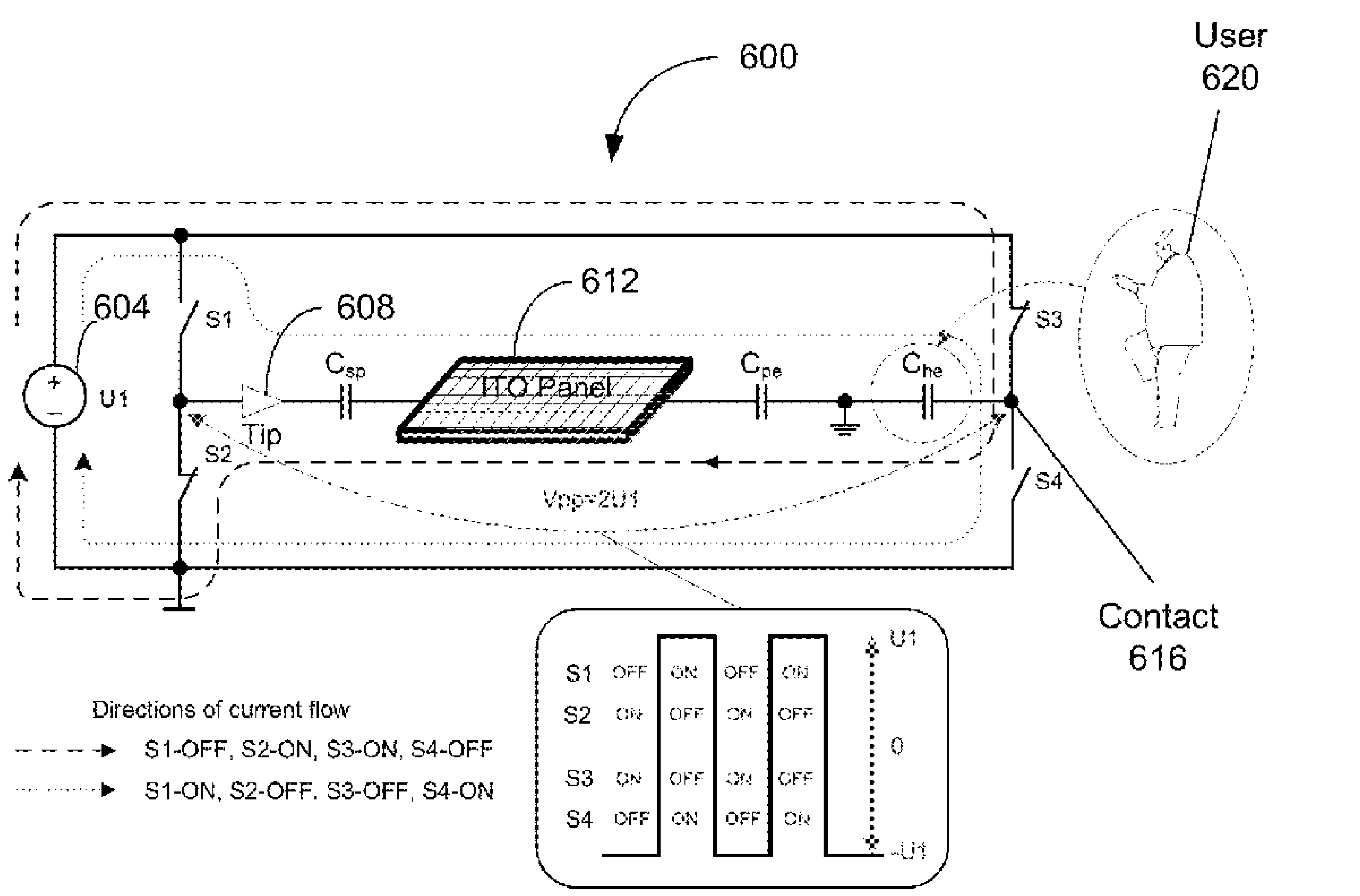
(57) **ABSTRACT**

A method and apparatus to increase a transmit (TX) signal generated by an active stylus without increasing the power consumption of the active stylus. In one aspect, the active stylus increases the amplitude of the TX signal. In another aspect, the active stylus increases the TX signal by providing the capacitance of a body of a user to the stylus.

18 Claims, 7 Drawing Sheets



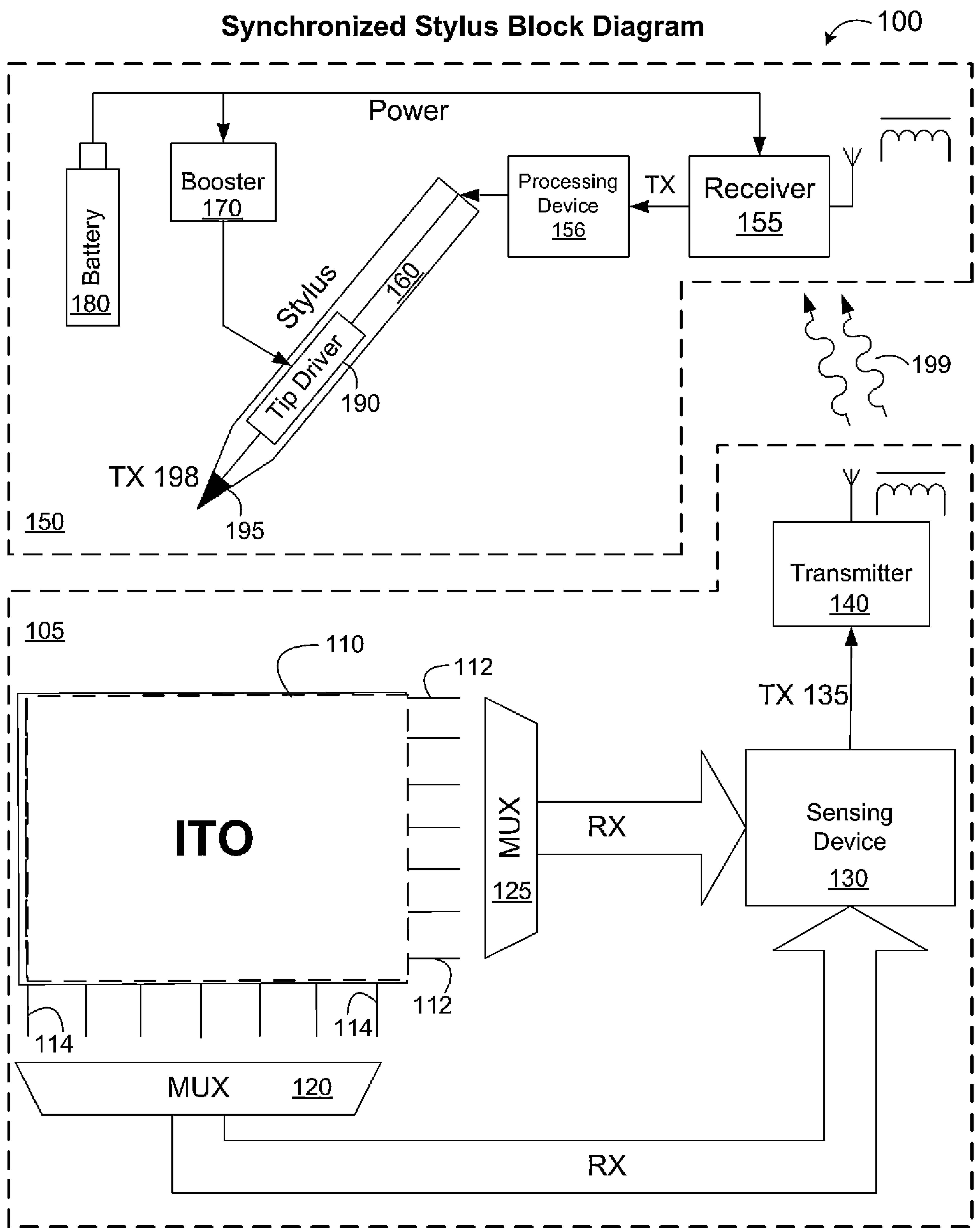

Synchronized Stylus Block Diagram
100
Power
Battery
180
Booster
170
Processing
Device
156
TX
Receiver
155
Stylus
160
Tip Driver
190
TX 198
195
150
199
Transmitter
140
105
110
112
TX 135
ITO
MUX
125
RX
Sensing
Device
130
112
114
114
MUX
120
RX

Fig. 1

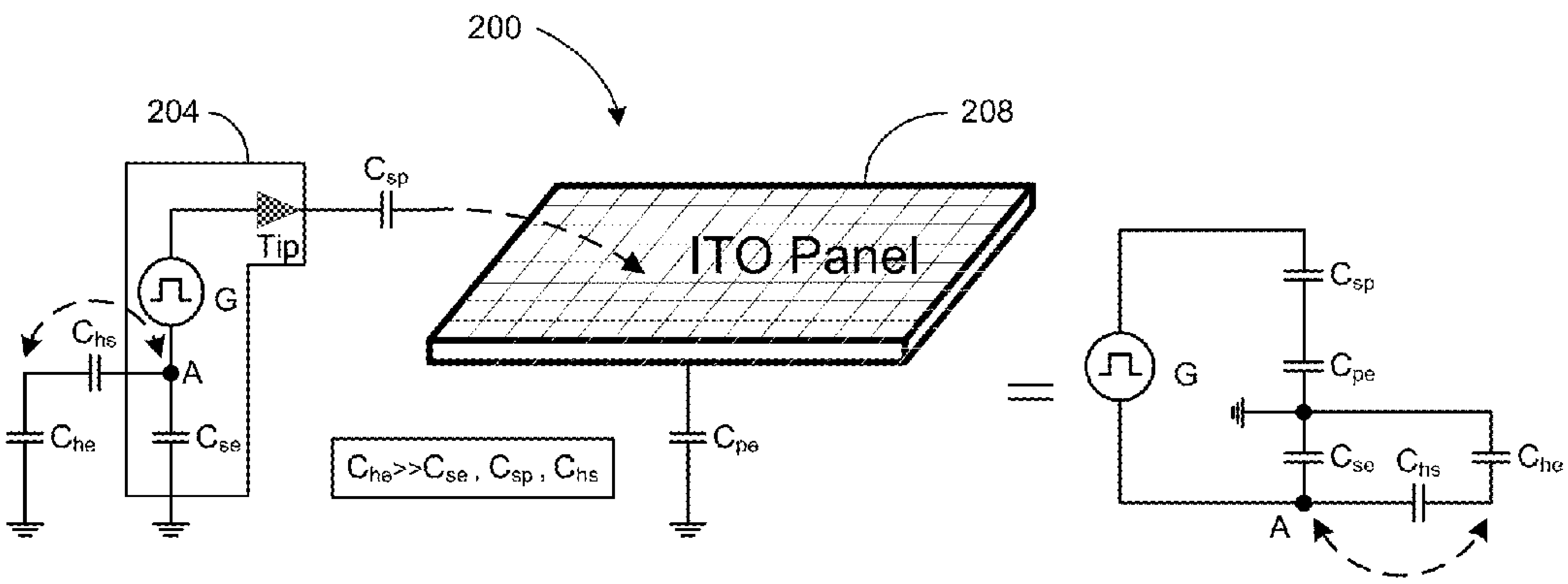


Fig. 2

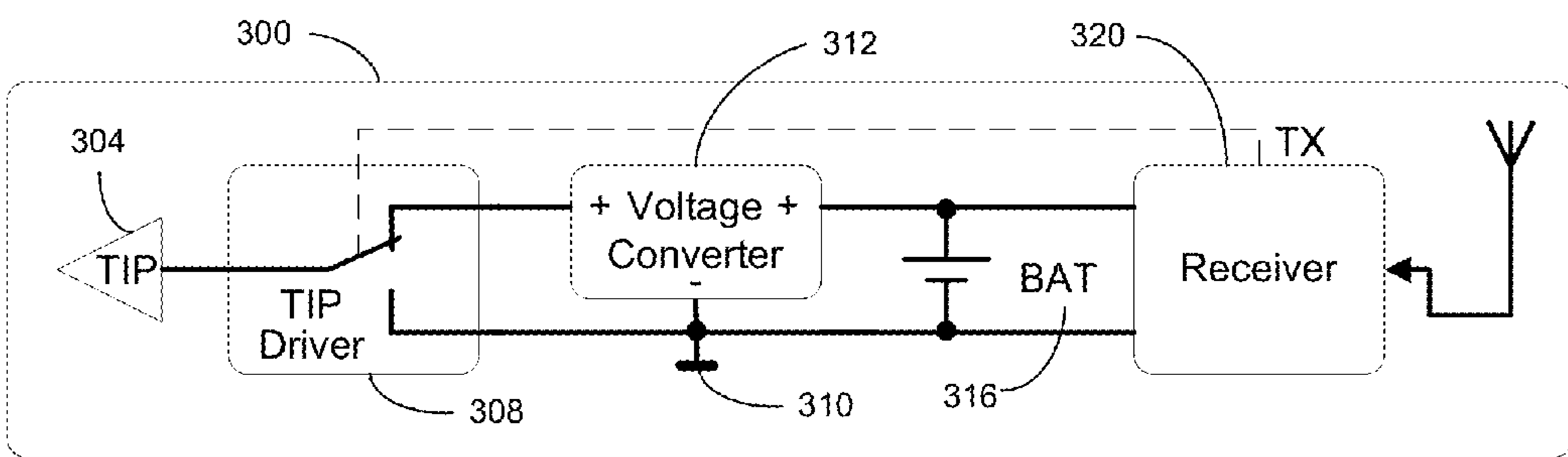


Fig. 3

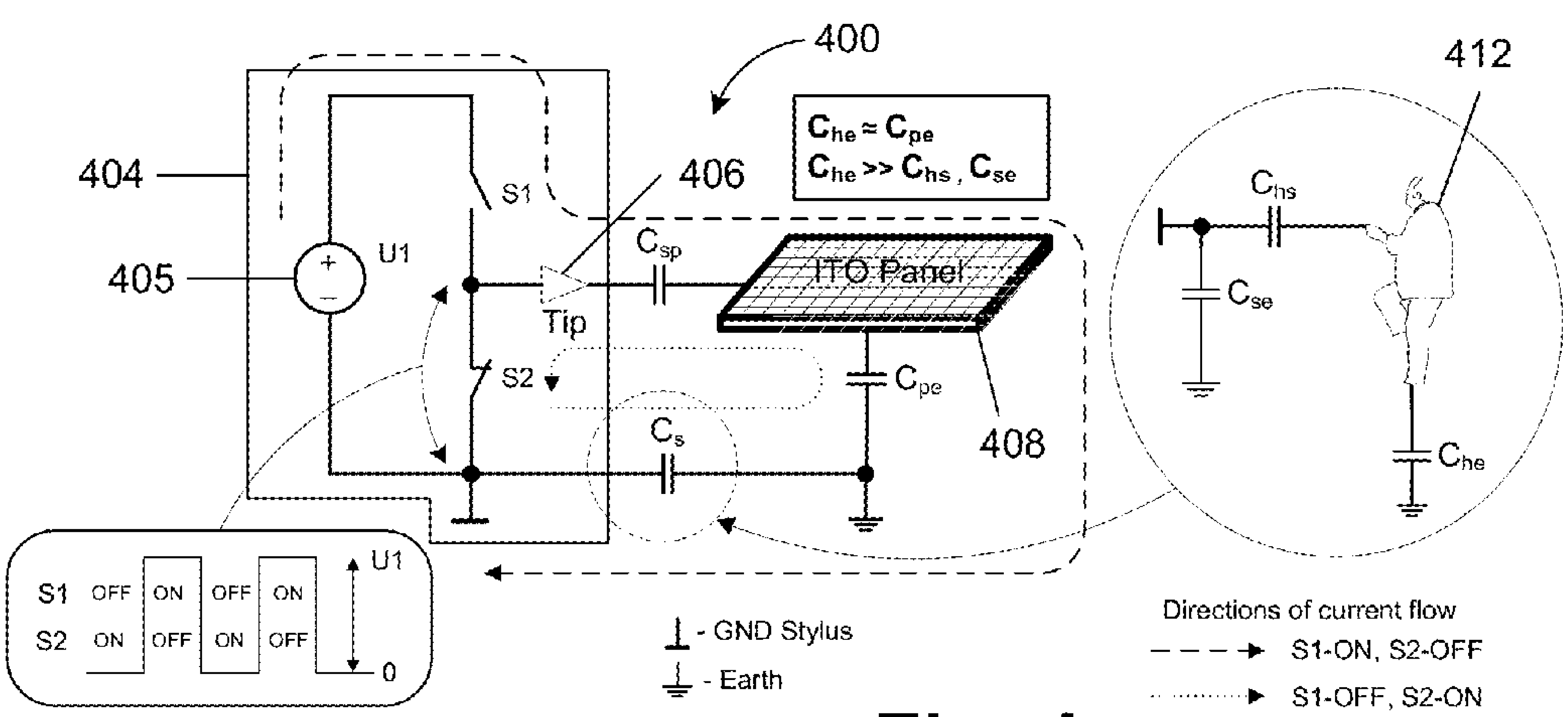


Fig. 4

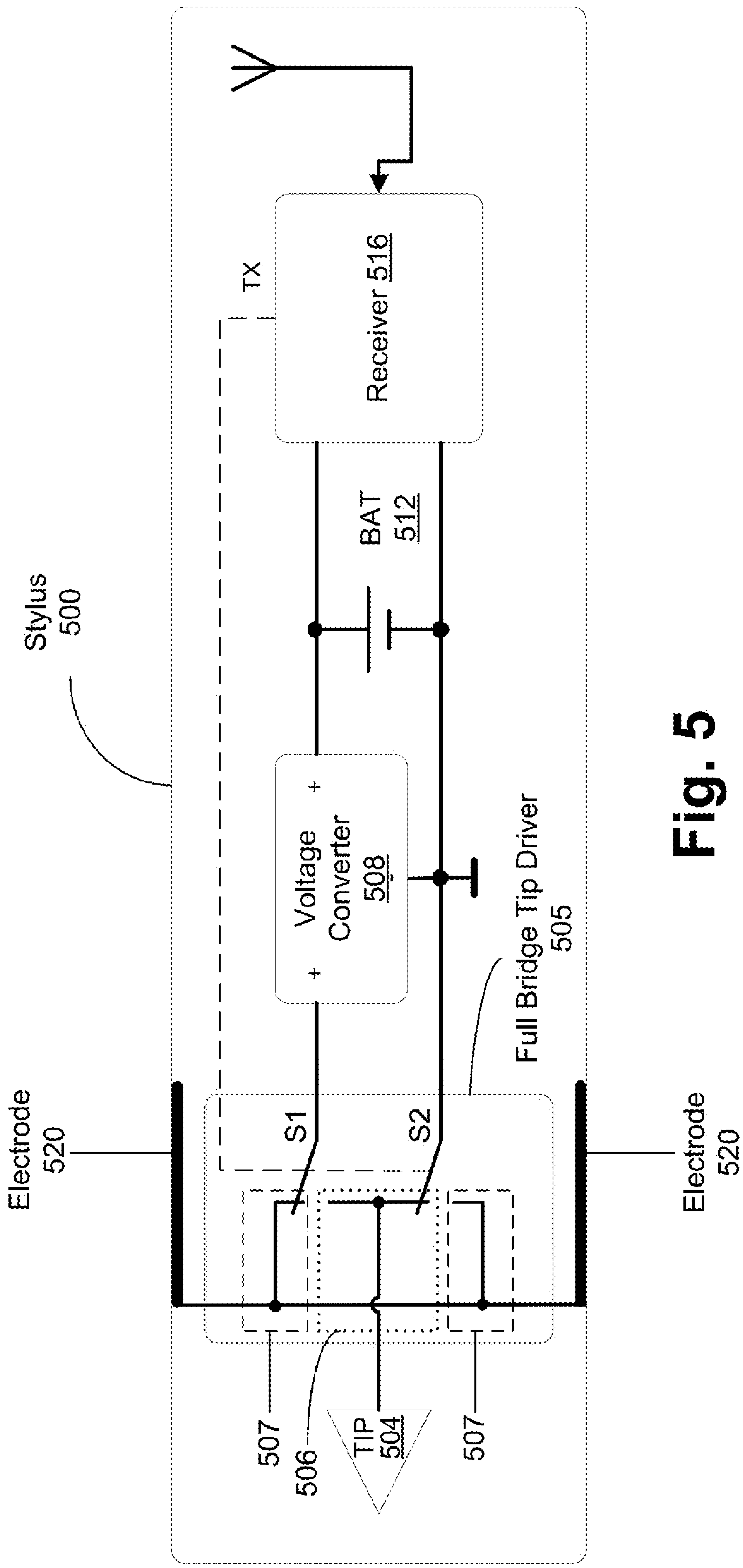

Stylus
500
Receiver 516
TX
BAT
512
Voltage
Converter
508
+
+
Full Bridge Tip Driver
505
Electrode
520
S1
S2
Electrode
520
507
506
TIP
504
507

Fig. 5

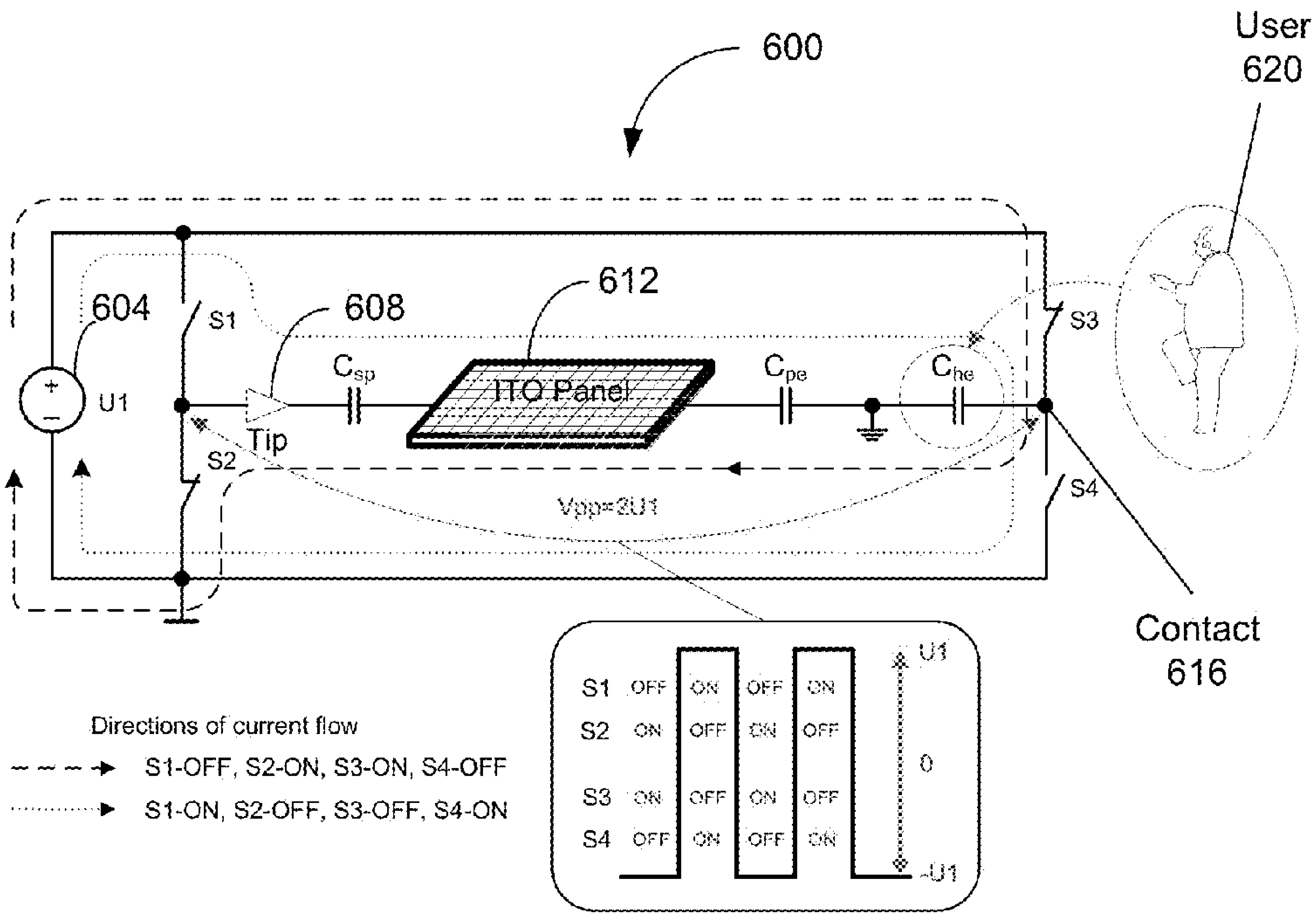

600
User
620
604
S1
608
612
U1
Tip
C_{sp}
ITO Panel
C_{pe}
C_{he}
S3
S2
S4
Vpp=2U1
Contact
616
Directions of current flow
S1-OFF, S2-ON, S3-ON, S4-OFF
S1-ON, S2-OFF, S3-OFF, S4-ON
S1 OFF ON OFF ON
S2 ON OFF ON OFF
S3 ON OFF ON OFF
S4 OFF ON OFF ON
U1
0
-U1

Fig. 6

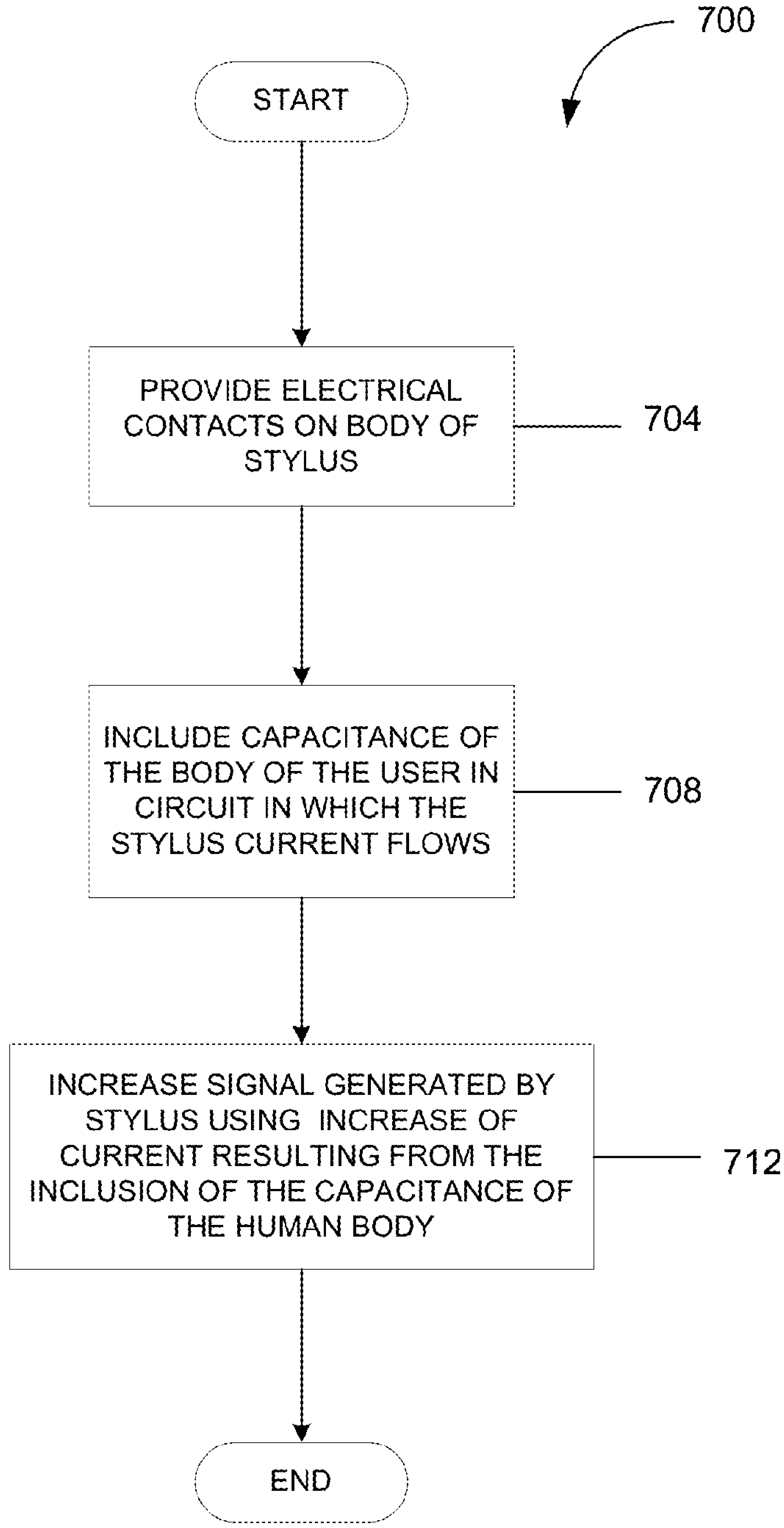

700
START
PROVIDE ELECTRICAL CONTACTS ON BODY OF STYLUS
704
INCLUDE CAPACITANCE OF THE BODY OF THE USER IN CIRCUIT IN WHICH THE STYLUS CURRENT FLOWS
708
INCREASE SIGNAL GENERATED BY STYLUS USING INCREASE OF CURRENT RESULTING FROM THE INCLUSION OF THE CAPACITANCE OF THE HUMAN BODY
712
END

Fig. 7

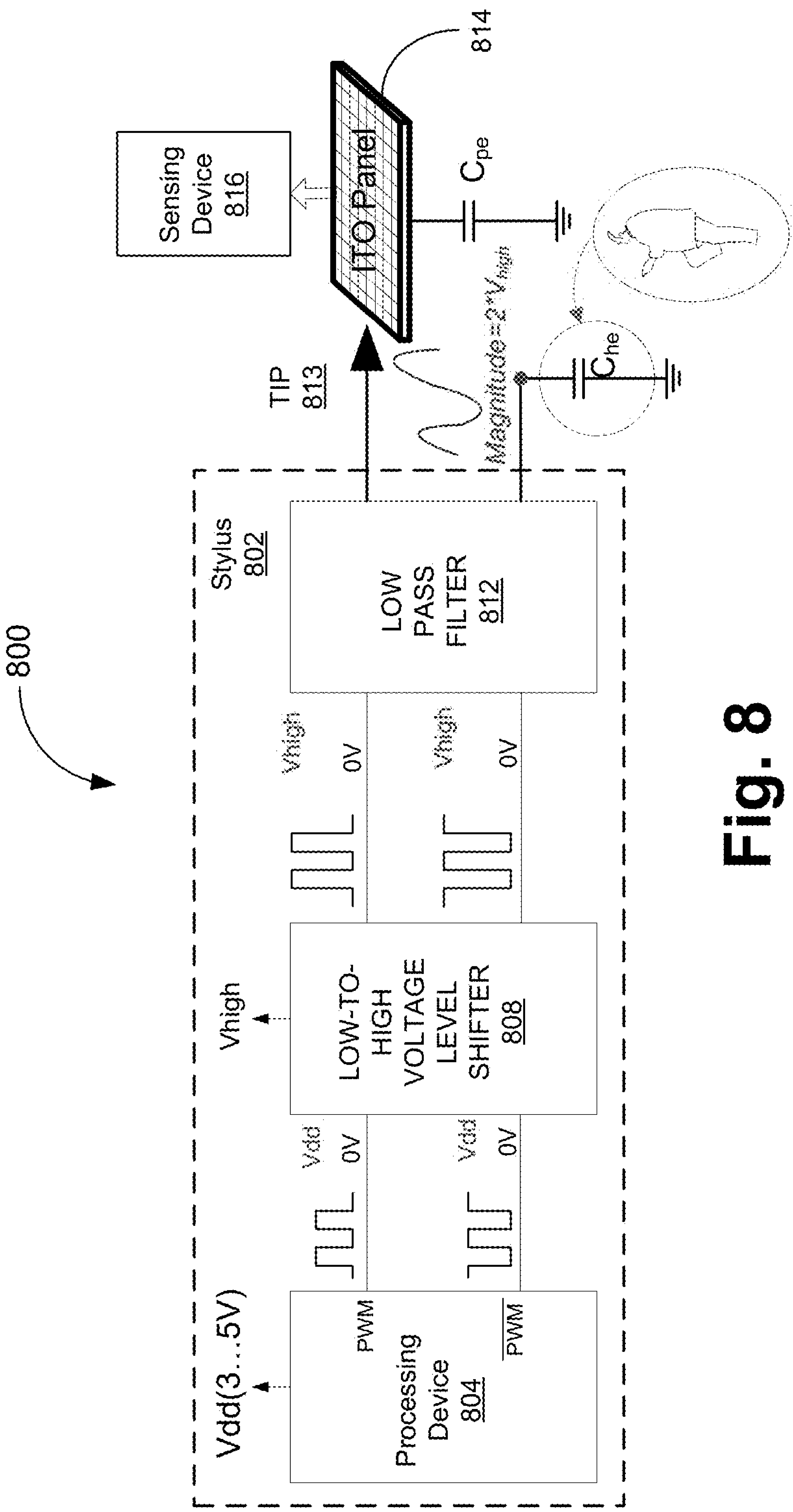

800
Stylus
802
Vdd(3…5V)
Processing
Device
804
PWM
PWM
Vdd
0V
Vdd
0V
Vhigh
LOW-TO-
HIGH
VOLTAGE
LEVEL
SHIFTER
808
Vhigh
0V
Vhigh
0V
LOW
PASS
FILTER
812
TIP
813
Magnitude=2*Vhigh
ITO Panel
814
Sensing
Device
816
Cpe
Cne

Fig. 8

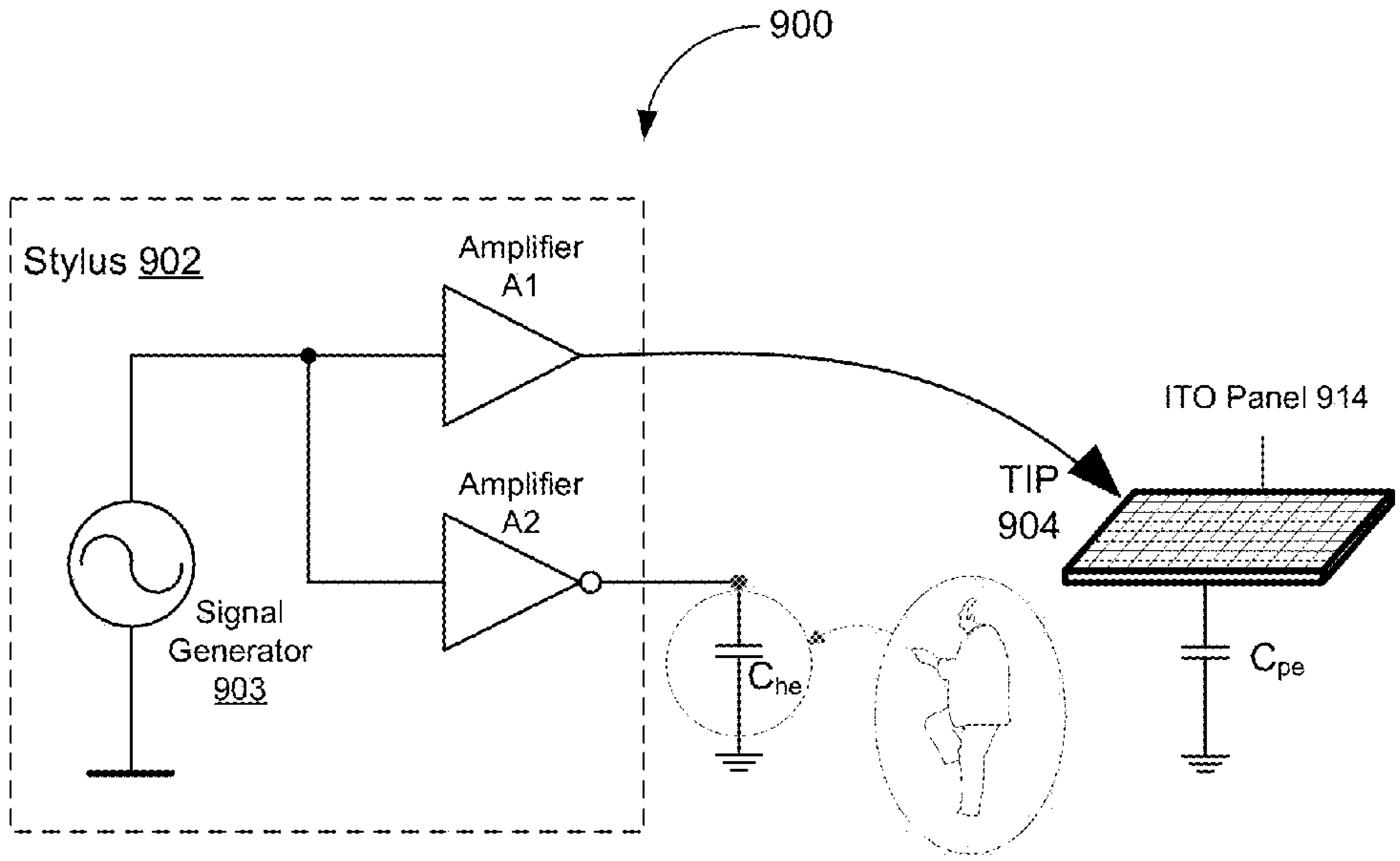

900
Stylus 902
Amplifier A1
Amplifier A2
Signal Generator 903
C_{he}
TIP 904
ITO Panel 914
C_{pe}

Fig. 9

FULL-BRIDGE TIP DRIVER FOR ACTIVE STYLUS

RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 61/512,359, filed on Jul. 27, 2011, the contents of which are hereby incorporated by reference herein.

TECHNICAL FIELD

This disclosure relates to the field of user interface devices and, in particular, to capacitive sensor devices.

BACKGROUND

The use of stylus with touch screens is well established, but some existing technologies have disadvantages of one or more of cost, performance and reliability. Touch screen designs have incorporated many different technologies including resistive, capacitive, inductive, and radio frequency sensing arrays.

A capacitive stylus uses a power source (e.g., a battery) to generate a transmit (TX) signal at the tip of the stylus. Increasing the TX signal (e.g., an electrical current) will allow the touch screen sensing system to better track the position of a stylus that is contacting or hovering over a touch screen (e.g., a capacitive sense array). However, increasing the TX signal will cause an increase in the power consumption of the capacitive stylus. The power source of the capacitive stylus may be not be capable of supplying the extra power (e.g., voltage) to increase the TX signal or the power source of the capacitive stylus may not be capable of supplying the extra power for an extended period of time. For example, the power source may be a battery which is not capable of generating the extra power to increase the TX signal. In another example, if the battery is capable of generating the extra power to increase the TX signal, this may result in draining the battery faster which shortens the time a user can use the capacitive stylus.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings.

FIG. **1** is a block diagram illustrating one embodiment of an electronic system for synchronizing a stylus to a host device.

FIG. **2** is a block diagram illustrating an electrical equivalent circuit diagram of a stylus on an ITO panel, according to one embodiment.

FIG. **3** is a block diagram of a stylus, according to one embodiment.

FIG. **4** is a block diagram illustrating an electrical equivalent circuit diagram of a stylus on an ITO panel, according to another embodiment.

FIG. **5** is a block diagram of a stylus, according to another embodiment.

FIG. **6** is a block diagram illustrating an electrical equivalent circuit diagram of a stylus on an ITO panel, according to one embodiment.

FIG. **7** is a flow diagram illustrating a method of increasing the TX signal generated by a stylus.

FIG. **8** is a block diagram of a stylus and an ITO panel, according to another embodiment.

FIG. **9** is a block diagram of a stylus and an ITO panel, according to another embodiment.

DETAILED DESCRIPTION

The following description sets forth numerous specific details such as examples of specific systems, components, methods, and so forth, in order to provide a good understanding of several embodiments of the present invention. It will be apparent to one skilled in the art, however, that at least some embodiments of the present invention may be practiced without these specific details. In other instances, well-known components or methods are not described in detail or are presented in simple block diagram format in order to avoid unnecessarily obscuring the present invention. Thus, the specific details set forth are merely exemplary. Particular implementations may vary from these exemplary details and still be contemplated to be within the scope of the present invention.

Embodiments of a method and apparatus are described to increase the TX signal generated by a capacitive stylus without increasing the power used by the capacitive stylus. In one embodiment, a full bridge driver is described. The full bridge driver may provide an electrical contact (e.g., an electrode) positioned on the body of the stylus to contact a human body (e.g., the body of the user). The electrical contact may form the stylus current return path. The full bridge driver may include a first bridge branch which is coupled to a capacitive tip of the stylus, and a second bridge branch which his coupled to the electrical contact. The full bridge driver may also enlarge the amplitude of the TX signal without increasing the power consumption of the capacitive stylus. In addition, the full bridge driver may reduce the power consumption of the stylus while maintaining a certain TX signal strength.

A capacitive stylus may be a synchronized capacitive stylus or an unsynchronized capacitive stylus. A synchronized capacitive stylus is stylus where the stylus TX signal is generated in frequency and phase relation to a synchronization signal generated by a host device (e.g., a touch screen). An unsynchronized capacitive stylus operates without any synchronization with a host controller. An unsynchronized stylus may transmit a TX signal according to one or more of internal procedures and algorithms.

FIG. **1** is a block diagram illustrating one embodiment of an electronic system **100** for synchronizing a stylus **150** to a host device **105**. The stylus **150** may be a capacitive stylus. The stylus **150** may also be an untethered stylus. The host device **105** includes a capacitive sense array **110**, multiplexor ("MUX") devices **120** and **125**, sensing device **130**, and transmitter **140**. In an embodiment, the capacitance sense array **110** is an all-points addressable mutual capacitance sense array (e.g., sense array **400**). In yet another embodiment, the capacitive sense array **110** is an Indium-Tin-Oxide ("ITO") panel. The capacitive sense array **110** ("sense array **110**" or "ITO **110**") is composed of rows **112** and columns **114** of electrodes. The rows **112** and columns **114** are coupled to the MUX's **125** and **120**, respectively. MUX's **120**, **125** are coupled to the sensing device **130**. The sensing device **130** is coupled to the transmitter **140**.

In one embodiment, the rows **112** and columns **114** of electrodes of the capacitive sense array **110** are configured to operate as TX and RX electrodes of a mutual capacitance sense array in a first mode to detect touch objects (e.g., rows **112** may be TX electrodes and columns **114** may be TX electrodes, or vice versa), and to operate as electrodes of a coupled-charge receiver in a second mode to detect a stylus on the same electrodes of the sense array. The stylus **150**, which generates a stylus TX signal **198** (e.g., an electrical current) when activated, is used to couple charge to the capacitive sense array, instead of measuring a mutual capacitance at an intersection of a RX electrode and a TX electrode (a sense element) as done during mutual capacitance sensing. The sensing device **130** does not use mutual capacitance or self-capacitance sensing to measure capacitances of the sense elements when performing a stylus can. Rather, the sensing device **130** measures a charge that is capacitively coupled between the capacitive sense array **110** and the stylus **150** as described herein.

In one embodiment, the sensing device **130** may be integrated into a processing device. Sensing device **130** may include analog I/O for coupling to an external component, including, but not limited to a touch-sensor pad, a touch screen, a touch-sensor slider (not shown), a touch-sensor buttons (not shown), and other devices. Sensing device **130** may be integrated into the integrated circuit (IC) of the processing device, or alternatively, in a separate IC. Alternatively, descriptions of sensing device **130** may be generated and compiled for incorporation into other integrated circuits. For example, behavioral level code describing sensing device **130**, or portions thereof, may be generated using a hardware descriptive language, such as VHDL or Verilog, and stored to a machine-accessible medium (e.g., CD-ROM, hard disk, floppy disk, etc.). Furthermore, the behavioral level code can be compiled into register transfer level ("RTL") code, a netlist, or even a circuit layout and stored to a machine-accessible medium. The behavioral level code, the RTL code, the netlist, and the circuit layout all represent various levels of abstraction to describe sensing device **130**. In another embodiment, the sensing device **130** may be a host controller.

In the depicted embodiment, the stylus block **150** comprises a receiver **155**, a processing device **156**, a battery **180**, a booster **170**, a tip driver **190**, and a stylus tip **195**. The processing device **156** may be one or more other processing devices known by those of ordinary skill in the art, such as a microprocessor or central processing unit, a controller, special-purpose processor, digital signal processor ("DSP"), an application specific integrated circuit ("ASIC"), a field programmable gate array ("FPGA"), or the like. In one embodiment, the processing device **156** may be a Programmable System on a Chip (PSoC®) processing device, developed by Cypress Semiconductor Corporation, San Jose, Calif.

The stylus block **150** represents the components that are housed within the stylus body **160** as depicted in FIG. **1**. The battery **180** is coupled to the booster **170** and receiver **155**. The booster **170** is coupled to the tip driver **190**. The processing device **156** is coupled to the receiver **155** and the tip driver **190**.

In an embodiment, the sensing device **130** generates and couples a TX signal **135** to the transmitter **140**. The transmitter **140** wirelessly couples the TX signal **135** to the receiver **155**. In one embodiment, the transmitter **140** inductively couples the TX signal **135** to the receiver **155**. In other embodiments, the transmitter may wirelessly couple the TX signal **135** in a variety of ways including radio frequency, optical, ultrasound, and other mediums that would be appreciated by one of ordinary in the art. The receiver **155** receives TX signal **199** from the transmitter **140** and couples demodulated TX signal to the stylus **150**.

In one embodiment, the TX **135** signal sent by the transmitter **140** is the same signal as the TX signal generated and applied to the ITO **110** on the TX lines **112** (or **114**) during finger position tracking. Alternatively, the TX signal **135** may be a different signal than the TX signal generated and applied to the ITO **110** and may have different signal characteristics (e.g., different frequency, phase, or code modulation). In another embodiment, the transmitter **140** sends a synchronization signal **199**, or timing data, whereby the stylus **150** generates the stylus TX signal **198** based on the synchronization signal **199** received by the receiver **155** from the transmitter **140**. In an embodiment, the synchronization signal **199** has different signal characteristics than the TX signal generated and applied to the ITO **110** during finger position tracking.

In one embodiment, the stylus **150** is a synchronized stylus. As discussed above, a stylus **150** may use the receiver **155** to receive a synchronization signal **199** transmitted by the transmitter **140**. In another embodiment, the stylus **150** may be an unsynchronized stylus. An unsynchronized stylus may operate without using the synchronization signal **199**. Thus, in an unsynchronized stylus, the receiver **155** may not be used, and may not be included in the stylus **150**.

In an embodiment, the battery **180** voltage may be provided by battery cells (e.g., 1.5V AAA cells). The booster **170** boosts the battery voltage delivered to the tip driver **190**, allowing the tip driver **190** to amplify the TX signal **135** to a higher voltage (e.g., 10V-20V). A high voltage stylus TX signal **198** may enable the host device **105** to detect the stylus **150** when it is "hovering," or in close proximity to the capacitive sense array **110**, but not physically touching an overlay disposed over the capacitive sense array **110**. A high voltage stylus TX signal **198** may also provide for faster and more robust detection by the sensing device **130**.

The stylus **150** capacitively couples the amplified stylus TX signal **198** from the stylus tip **195** (e.g., a tip electrical current) to the capacitive sense array **110**. The rows **112** and columns **114** of electrodes (configured as RX electrodes in stylus position tracking mode) sense the stylus TX signals **198** and send the received stylus TX signals **198** to the sensing device **130** via MUX's **120** and **125**. In an embodiment, the stylus TX signals **198** are referred to as RX signals once they are sensed by one or more of the rows **112** and columns of electrodes on the ITO **110**. As shown, the sensing device **130** receives the stylus TX signal **198** by RX'ing on both the rows **112** and columns **114** of electrodes of capacitive sense array **110**. In an embodiment, the sensing device **130** performs a stylus scan of the rows **112** and columns **114** of capacitance sense array **110** when sensing the stylus TX signal **198**. The sensing device **130** determines the location of the stylus **150** based on the relative strength of the TX signal **198** on each of the rows **112** and columns **114** elements of the capacitance sense array **110**.

The synchronized operation of the host **105** and stylus **150** enables the sensing device **130** to substantially simultaneously track a passive touch object (e.g., finger) and stylus **150** on the sense array **110**. Synchronization ensures that the stylus **150** transmits a stylus TX signal **198** during a period when the sensing device **130** is not TX'ing for passive touch object sensing.

FIG. **2** is a block diagram **200** illustrating the electrical equivalent circuit diagram of a stylus **204** on an ITO panel **208**, according to an embodiment. The block diagram **200** includes the ITO panel **208** and the stylus **204**. C_{sp} is the capacitance between the tip of the stylus **204** and the ITO panel **208**. C_{se} is the self-capacitance of the stylus **204**, relative to ground (e.g., earth ground). C_{pe} is the self-capacitance of the ITO panel **208** relative to ground. C_{hs} is the capacitance between the user and the stylus. C_{he} is the self-capacitance of a body of the user (e.g., a human body), relative to ground. Capacitance C_{he} is larger than C_{hs}. However, capacitances C_{he} and C_{hs} are connected sequentially and the resulting capacitance will be limited to the smaller capacitance C_{hs}. As discussed above, the stylus **204** may transmit a TX signal from the tip of the stylus **204**. The TX signal from the stylus **204** is divided among the capacitors C_{sp}, C_{pe}, and C_{se}+C_{hs}. Although capacitance C_{he} is larger than capacitances C_{se} and C_{sp}, the self-capacitance of the user's body (e.g., C_{he}) does not affect the operation of the stylus **204** and the ITO panel **208** because the user's body (e.g., the human body) is connected through the smaller capacitance C_{hs}. The TX signal transmitted from the stylus is flows through the capacitance C_{pe}. In one embodiment, the TX signal can be increased by reducing the impact of capacitances C_{se} or C_{sp}. In another embodiment, providing an electrode (which introduces the capacitance of the user's body C_{he}) between the capacitances C_{se} and C_{hs} (e.g., point A in FIG. **2**), reduces the impact of the capacitance C_{hs} on the circuit. By introducing the larger capacitance C_{he} to the circuit, the resistance of the circuit is decreased and more electrical current can flow through the circuit, thus increasing the TX signal transmitted by the stylus.

FIG. **3** is a block diagram of a stylus **300**, according to one embodiment. The stylus **300** may an untethered, synchronized, capacitive stylus. The stylus **300** includes a tip **304**, a tip driver **308** which includes a switch, a voltage converter **312**, a battery **316**, and a receiver **320**. The receiver **320** may receive a synchronization signal from a transmitter, such as the transmitter **140** of FIG. **1**. The battery **316** may be used to provide power for the receiver **320**. The battery **316** may also provide a voltage (e.g., an electrical current) to voltage converter **312**. The voltage converter may boost the voltage provided by the battery **316** to increase the TX signal transmitted by the tip **304**. In one embodiment, the tip driver **308** includes a switch, which switches (e.g., oscillates) between the internal ground of the stylus **310**, and the voltage received from the voltage converter **312**. When the switch connects to (e.g., switches to) the voltage converter **312**, the electrical current (e.g., the TX signal) received from the voltage converter **312** is passed to the tip **304**. When the switch connects to the internal ground of the stylus, no electrical current is passed to the tip **304**. The tip driver **308** may be referred to as a push-pull driver.

FIG. **4** is a block diagram **400** illustrating the electrical equivalent circuit diagram of a stylus **404** on an ITO panel **408**, according to another embodiment. The block diagram **400** includes the ITO panel **408** and the stylus **404**.

The stylus **404** includes two switches **S1** and **S2**, a power source **405**, and a tip **406**. In one embodiment, the switches **S1** and **S2** may be mutually exclusive switches. For example, if switch **S1** is connected (e.g., on), then switch **S2** is not connected (e.g., off), and vice versa. Switches **S1** and **S2** may correspond to the switch in the tip driver **308** of FIG. **3**. When switch **S1** is on and switch **S2** is off, an electrical current (with an amplitude of **U1**) provided by the power source **405** is passed through to the tip **406** (e.g., C_{sp}, C_{pe} and C_s are charged by the power source). The flow of the electrical current when switch **S1** is on and switch **S2** is off is shown by the dashed line going clockwise in FIG. **4**. When switch **S1** is off and switch **S2** is on, C_{sp}, C_{pe} and C_s are discharged and current flows through the switch **S2** and the tip **406** in the opposite direction. The flow of the electrical current when switch **S1** is off and switch **S2** is on is shown by the dotted line going counter-clockwise in FIG. **4**. As shown in FIG. **4**, the voltage of the electrical current is unipolar, e.g., it varies between the value 0 and **U1**.

C_{sp} is the capacitance between the tip **406** of the stylus **404** and the ITO panel **408**. C_{pe} is the self-capacitance of the ITO panel **408** relative to ground. C_s is a combination of C_{hs}, C_{se}, and C_{he}. C_{he} is the self-capacitance of a body of the user **412** (e.g., a human body), relative to ground. C_{se} is the self-capacitance of the stylus **404**, relative to ground (e.g., earth ground). C_{hs} is the capacitance between the user **412** and the stylus **404**. C_s may be calculated using the following equation:

$$C_s = \frac{C_{hs} \cdot C_{he}}{C_{hs} + C_{he}} + C_{se} \approx C_{hs} + C_{se} \tag{1}$$

As shown in FIG. **4**, C_{he} is commensurate with C_{pe}. In addition, C_{he} is also larger than C_{hs} and C_{se}. As discussed above, the capacitance of the user's body (e.g., C_{he}) has little or no effect on the operation of the ITO panel **408** and the stylus **404**. Capacitances C_{he} and C_{hs} are connected sequentially so the resulting capacitance will be commensurate with (e.g., limited by) C_{hs}.

FIG. **5** is a block diagram of a stylus **500**, according to another embodiment. The stylus **500** includes a full bridge tip driver **505**, a tip **504**, electrodes **520**, a voltage converter **508**, a battery **512**, and a receiver **516**. As discussed above, in one embodiment, the stylus **500** may be a synchronized stylus, which uses the receiver **516** so receive a synchronization signal. In another embodiment, the stylus **500** may be an unsynchronized stylus, and the receiver **516** may not be included in the stylus **500**.

Similar to FIG. **3**, the battery **512** may provide power to the receiver **516** and to the voltage converter **508**, and the tip **504** may transmit a TX signal to an ITO panel. The receiver **516** may receive a synchronization signal from the ITO panel.

The full bridge tip driver **505** includes two bridge branches **506** and **507**. The first bridge branch **506** (shown as a dotted box) is coupled to the tip **504**. The second bridge branch **507** (shown as two lined boxes) is coupled to the electrodes **520**. The electrodes **520** may be used to connect with the body of the user (e.g., a human body). The electrodes **520** may form the current return path for the stylus **500**. Adding the capacitance of the human body to the current return path decreases the resistance of the circuit formed between the ITO panel and the stylus **500**. Decreasing the resistance of the circuit allows more electrical current to flow through the circuit, which increases the TX signal transmitted by the tip **504**.

FIG. **6** is a block diagram **600** illustrating an electrical equivalent circuit diagram of a stylus on an ITO panel, according to one embodiment. The block diagram **600** includes a power source **604**, four switches **S1**, **S2**, **S3**, and **S4**, a tip **608**, a contact **616**, an ITO panel **612**, and a user **620**.

The power source **604**, the tip **608**, contact **616**, and the four switches **S1**, **S2**, **S3**, and **S4** are part of the stylus. The contact **616** is coupled to one or more electrical contacts (e.g., electrodes) which are in turn, coupled to the body of the user **620**. The electrical contacts may also be part of the stylus. As discussed above, C_{sp} is the capacitance between the tip **608** of the stylus and the ITO panel **612**. C_{pe} is the self-capacitance of the ITO panel **612** relative to ground. C_{he} is the self-capacitance of the body of the user **620** (e.g., a human body), relative to ground. The electrical current received from the body of the user **620** is used to increase the TX signal (e.g., increase the amplitude) transmitted by tip **608** of the stylus to the ITO panel **612**.

In one embodiment, the switches **S1** and **S2** may be mutually exclusive switches. For example, if switch **S1** is connected (e.g., on), then switch **S2** is not connected (e.g., off), and vice versa. In another embodiment, the switches **S3** and **S4** may also be mutually exclusive switches, similar to switches **S1** and **S2**. In one embodiment, the switches **S1** and **S2** are coupled to the tip **608** and may form part of the first bridge branch, as discussed above in FIG. **5**. In another embodiment, the switches S**3** and S**4** are coupled to an electrical contact (e.g., an electrode) on the stylus ad may form the second bridge branch, as discussed above in FIG. **5**. In one embodiment, when switches S**1** and S**4** are off and switches S**2** and S**3** are on, the tip **608** transmits a TX signal (e.g., an electrical current) with an amplitude of −U**1** and when switches S**1** and S**4** are on and switches S**2** and S**3** are off, the tip **608** transmits a TX signal (e.g., an electrical current) with an amplitude of U**1**.

As shown in FIG. **6**, the flow of the electrical current when switches S**1** and S**4** are off and switches S**2** and S**3** are on, is shown by the dashed line. The flow of the electrical current when switches S**1** and S**4** are on and switches S**2** and S**3** are off, is shown by the dotted line.

Providing an electrode in the stylus and coupling the an electrical current from the human body to the stylus through the contact **616** and the switches S3 and S4 allows the stylus to transmit a TX signal (e.g., an electrical current) with an ranging from −U**1** to U**1**. This range of −U**1** to U**1** is double the range of 0 to U**1**, shown in FIG. **4**. In other words, the amplitude of the TX signal (e.g., electrical current) transmitted by the tip **608** is double compared to the amplitude of the TX signal transmitted by the tip **406** shown in FIG. **4**. The amplitude of the TX signal is doubled by using the full bridge tip driver shown in FIG. **5**. By coupling the user's body (e.g., the capacitance of the user's body) to the circuit via the electrodes and contact **616**, the capacitance of the user's body C_{he} replaces the capacitance C_s (shown in FIG. **4**). Replacing the smaller capacitance C_s with the larger capacitance C_{he} decrease the resistance of the circuit, which results in an increase in the flow of current through the electrical circuit. The increase in the amplitude of the TX signal and the increase in the current which flows through the circuit are achieved without increasing the power consumption of the stylus (e.g., without increasing the amount of power drawn from the battery).

In one embodiment, the increase in the TX signal generated by the stylus increases the signal-to-noise ratio (SNR) of the TX signal. Increasing the TX signal (e.g., increasing the SNR) allows the ITO panel **612** to better detect the stylus position when the stylus is contacting the ITO panel **612** or hovering over the ITO panel. In one exemplary embodiment, a stylus without an electrode (e.g., an electrical contact) may have a TX signal with an SNR of 15 when the stylus is in contact with the ITO panel **612** and an SNR of 5.8 when the stylus is hovering over the ITO panel **612** (e.g., stylus is ~15 mm away from the ITO panel). In another exemplary embodiment, providing an electrode to receive introduce the capacitance of the human body of the user **620** into the circuit between the stylus and the ITO panel **612** may increase the SNR of the TX signal to 40 when the stylus is in contact with the ITO panel **612** and to 16, when the stylus is hovering over the ITO panel **612**. In one embodiment, this increase in TX signal (achieved by providing an electrode to introduce the capacitance of the body of the user **620** into the circuit) may allow the stylus to consume less power from the power source **604** of the stylus. For example, if the ITO panel **612** can accurately detect a stylus contact when the SNR of the TX signal of the stylus is 15, then the power used from the power source **604** may be decreased, because the SNR of the TX signal is 40 due to the increased capacitance and decreased resistance of the circuit resulting from introducing the capacitance of the body of the user **620** into the circuit. The increased capacitance and decreased resistance of the circuit allows more current to flow through the circuit which increases the TX signal transmitted by the stylus. The increased current flow resulting from adding the capacitance of the user's body to the circuit may be used to offset the amount of power used from the power source **604**.

FIG. **7** is a flow diagram illustrating a method **700** of increasing the TX signal generated by a stylus. In one embodiment, the TX signal may be increased by increasing the amplitude of the TX signal. The method **700** may be performed by a stylus that comprises hardware (e.g., circuitry, electrodes, switches, dedicated logic, programmable logic, microcode), software (e.g., instructions run on a processing device to perform hardware simulation), or a combination thereof. The stylus may be configured to increase the TX signal generated by the stylus, without increasing the power consumption of the stylus. In one embodiment, method **700** may be performed by stylus **500** as shown in FIG. **5**.

The method **700** begins with providing one or more electrical contacts (e.g., electrodes) on the body of the stylus (block **704**). In one embodiment, the one or more electrical contacts may directly contact the body of a user. In another embodiment, a material (e.g., plastic, etc.) may be positioned between the one or more electrical contacts such that the electrical contacts do not come into direct contact with the body of the user. At block **708**, the capacitance of the body of the user is introduced to the circuit in which the stylus current (e.g., electrical current) flows, via the electrical contacts. The increased capacitance resulting from the introduction of the capacitance of the human body increases the amount of current which flows through the stylus to the ITO panel, due to the decrease in the resistance of the circuit (block **712**). The increase in the amount of current which flows through the stylus increases the signal (e.g., the TX signal) generated by the stylus and also results in an increase (e.g., doubling) in the amplitude of the TX signal.

FIG. **8** is a block diagram **800** of a stylus **802** and an ITO panel **814**, according to another embodiment. The block diagram includes the stylus **802**, an ITO panel **814**, and a sensing device (e.g., a processing device) **816**. In one embodiment, the stylus **802** may convert a TX signal from a square signal (e.g., a square shape) to a sinusoidal signal (e.g., a sine wave shape).

The stylus **802** includes a processing device **804** which regulates the voltage supplied to low-to-high voltage level shifter **808**. The low-to-high voltage level shifter **808** increases (e.g., boosts) the voltage received from the processing device **804**. The increased voltage is passed from the low-to-high voltage level shifter **808** to the low pass filter (LPF) **812**. The LPF **812** converts the square signal into a sinusoidal signal, which is transmitted by the tip **813** of the stylus **802** to the ITO panel **814**. As discussed above, C_{pe} is the self-capacitance of the ITO panel **814** relative to ground and C_{he} is the self-capacitance of a body of the user (e.g., a human body), relative to ground. In one embodiment, the LPF **812** may be connected to the body of the user, which replaces the capacitance C_s (shown in FIG. **4**) with the larger capacitance C_{he}, which allows more current to flow through the circuit, as discussed above.

In one embodiment, the stylus **802** may convert the TX signal from the square signal to the sinusoidal signal depending on whether the ITO panel **814** can better detect a square signal or a sinusoidal signal. Depending on the type of the ITO panel **814**, the ITO panel may detect square signals better than it can detect sinusoidal signals, or vice versa. For example, the stylus **802** may convert a TX signal from a square signal to a sinusoidal signal if the ITO panel **814** can better detect sinusoidal signals.

FIG. **9** is a block diagram **900** of a stylus **902** and an ITO panel **914**, according to another embodiment. The stylus **902** includes a signal generator **903**, a tip **904**, an amplifier A**1**, and an inverted amplifier A**2**. In one embodiment, the signal generator **903** may be a sinusoidal signal generator (e.g., a generator which generates sinusoidal shaped signals). The amplifier A**1** is coupled to the tip **904**. The signal generated by the signal generator **903** is amplified by the amplifier A**1** and transmitted to the ITO panel **914** via the tip **904**. The inverted amplifier A**2** is coupled to the body of a user via one or more electrical contacts (e.g., electrodes) on the body of the stylus **902**. The inverted amplifier A**2** inverts (e.g., reverses) the signal received from the signal generator **903** and transmits the inverted signal to the user via the one or more electrical contacts. In one embodiment, the inverted amplifier A**2** may be connected to the body of the user which replaces the capacitance C_s (shown in FIG. **4**) with the larger capacitance C_{he}, which allows more current to flow through the circuit, as discussed above.

Embodiments of the present invention include various operations. These operations may be performed by hardware components, software, firmware, or a combination thereof. Any of the signals provided over various buses described herein may be time multiplexed with other signals and provided over one or more common buses. Additionally, the interconnection between circuit components or blocks may be shown as buses or as single signal lines. Each of the buses may alternatively be one or more single signal lines and each of the single signal lines may alternatively be buses.

Certain embodiments may be implemented as a computer program product that may include instructions stored on a machine-readable medium. These instructions may be used to program a general-purpose or special-purpose processor to perform the described operations. A machine-readable medium includes any mechanism for storing or transmitting information in a form (e.g., software, processing application) readable by a machine (e.g., a computer). The machine-readable medium may include, but is not limited to, magnetic storage medium (e.g., floppy diskette); optical storage medium (e.g., CD-ROM); magneto-optical storage medium; read-only memory (ROM); random-access memory (RAM); erasable programmable memory (e.g., EPROM and EEPROM); or another type of medium suitable for storing electronic instructions. In one embodiment, the machine-readable medium may comprise a non-transitory machine-readable medium.

Additionally, some embodiments may be practiced in distributed computing environments where the machine-readable medium is stored on and executed by more than one computer system. In addition, the information transferred between computer systems may either be pulled or pushed across the communication medium connecting the computer systems.

The digital processing device(s) described herein may include one or more general-purpose processing devices such as a microprocessor or central processing unit, a controller, or the like. Alternatively, the digital processing device may include one or more special-purpose processing devices such as a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or the like. In an alternative embodiment, for example, the digital processing device may be a network processor having multiple processors including a core unit and multiple microengines. Additionally, the digital processing device may include any combination of general-purpose processing device(s) and special-purpose processing device(s).

Although the operations of the method(s) herein are shown and described in a particular order, the order of the operations of each method may be altered so that certain operations may be performed in an inverse order or so that certain operation may be performed, at least in part, concurrently with other operations. In another embodiment, instructions or sub-operations of distinct operations may be in an intermittent or alternating manner.

In the foregoing specification, the invention has been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader scope of the invention as set forth in the appended claims. The specification and drawings are, accordingly, to be regarded in an illustrative sense rather than a restrictive sense.

What is claimed is:

1. An active stylus comprising:
a full bridge tip driver comprising:
a first bridge branch output coupled to a tip of the active stylus; and
a second bridge branch output coupled to an electrical contact positioned in a casing of the active stylus, wherein the electrical contact coupled to the second bridge branch output is to provide a capacitance of a body of a user to a second bridge branch.

2. The active stylus of claim **1**, wherein the full bridge driver is configured to decrease the resistance in the active stylus and increase a flow of electrical current through the active stylus.

3. The active stylus of claim **1**, wherein the active stylus comprises a synchronized stylus.

4. The active stylus of claim **1**, wherein the active stylus comprises an unsynchronized stylus.

5. The active stylus of claim **1**, wherein the active stylus comprises an untethered stylus.

6. The active stylus of claim **1**, further comprising a power source coupled to the full bridge tip driver.

7. The active stylus of claim **1**, further comprising a signal converter configured to convert the tip electrical current into a sinusoidal signal.

8. The active stylus of claim **1**, further comprising a receiver, coupled to the full bridge tip driver, wherein the receiver is configured to receive transmissions from a capacitive sense array.

9. The active stylus of claim **8**, further comprising a processing device configured to process the transmissions received from the capacitive sense array.

10. An active stylus comprising:
an electrical contact positioned on the active stylus; and
means for increasing an amplitude of a tip electrical current generated by the active stylus without increasing power consumption of the active stylus by providing the capacitance of a body of a user to the active stylus through the electrical contact as a first output of a full bridge driver, wherein the full bridge driver comprises a second output coupled to a tip of the active stylus.

11. The active stylus of claim **10**, further comprising:
means for converting the tip electrical current into a sinusoidal signal.

12. The active stylus of claim **10**, further comprising:
a power source coupled to the means for increasing amplitude.

13. The active stylus of claim **10**, further comprising:
means for receiving transmissions from a capacitive sense array.

14. The active stylus of claim 13, further comprising:
means for processing the transmissions received from the capacitive sense array.

15. A method comprising:
providing an electrical contact on a stylus; and
increasing a tip electrical current generated by the stylus by providing a capacitance of a body of a user to the stylus as a first output of a full bridge driver through the electrical contact, wherein the full bridge driver comprises a second output coupled to a tip of the stylus.

16. The method of claim 15, wherein the electrical contact is configured to directly contact the body of the user.

17. The method of claim 15, wherein the tip electrical current generated by the stylus comprises a digital signal.

18. The method of claim 15, further comprising:
converting the tip electrical current generated by the stylus into a sinusoidal signal.

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